

## Claims

WHAT IS CLAIMED IS:

1. A computer program product encoding a computer program for executing on a computer system a computer process for managing allocation of program data in a target program between one or more thread-specific heaps and at least one shared heap, the program data including thread-specific data and shared data, the computer process comprising:

5 analyzing the target program to distinguish between the thread-specific data of a first program thread and the shared data;

configuring the target program to allocate the thread-specific data of the first program thread to a first thread-specific heap, responsive to the analyzing operation; and

10 configuring the target program to allocate the shared data to the shared heap, responsive to the analyzing operation.

2. The computer program product of claim 1 wherein the analyzing operation comprises analyzing the target program to distinguish among the thread-specific data of the first program thread, the thread-specific data of a second program thread, and the shared data, and wherein the computer process further comprises:

5 configuring the target program to allocate the thread-specific data of the second program thread to a second thread-specific heap, responsive to the analyzing operation.

3. The computer program product of claim 1 wherein the analyzing operation comprises:  
identifying program data in the target program as the thread-specific data of the first  
program thread, if the program data is not referenced by any other program thread of the target  
program.

4. The computer program product of claim 1 wherein the analyzing operation comprises:  
identifying program data in the target program as the thread-specific data of the first  
program thread based on a thread escape analysis.

5. The computer program product of claim 1 wherein target program further includes a  
second program thread and the analyzing operation comprises:  
identifying program data in the target program as the shared data, if the program data is  
referenced by the first program thread and the second program thread of the target program.

6. The computer program product of claim 1 wherein the analyzing operation occurs  
prior to execution of the target program.

7. The computer program product of claim 1 wherein the operation of configuring the  
target program to allocate the thread-specific data comprises:

replacing an original allocation instruction in the target program with a new instruction  
that allocates the thread-specific data of the first program thread to the first thread-specific heap

5 associated with the first program thread.

8. The computer program product of claim 1 wherein the operation of configuring the target program to allocate the thread-specific data comprises:

leaving an original allocation instruction in the target program to allocate the thread-specific data of the first program thread to the first thread-specific heap associated with the first  
5 program thread.

9. The computer program product of claim 1 wherein the operation of configuring the target program to allocate the shared data comprises:

leaving an original allocation instruction in the target program to allocate the shared data to the shared heap.

10. The computer program product of claim 1 wherein the operation of configuring the target program to allocate the shared data comprises:

replacing an original allocation instruction in the target program with a new instruction that allocates the shared data to the shared heap.

11. The computer program product of claim 1 wherein the operation of configuring the target program to allocate the thread-specific data comprises:

configuring an allocation parameter associated with the thread-specific data indicating that the thread-specific data of the first program thread is to be allocated in the one of the thread-specific  
5 specific heaps.

12. The computer program product of claim 1 wherein the operation of configuring the target program to allocate the thread-specific data further comprises:

allocating the thread-specific data of the first program thread to the first thread-specific heap associated with the first program thread, responsive to the allocation parameter.

13. The computer program product of claim 1 wherein the operation of configuring the target program to allocate the shared data comprises:

configuring an allocation parameter associated with the shared data indicating that the shared data is to be allocated in the shared heap.

14. The computer program product of claim 13 wherein the operation of configuring the target program to allocate the shared data further comprises:

allocating the shared data to the shared heap, responsive to the allocation parameter.

15. The computer program product of claim 1 wherein the operation of configuring the target program to allocate the thread-specific data occurs prior to execution of the target program.

16. The computer program product of claim 1 wherein the operation of configuring the target program to allocate the shared data occurs prior to execution of the target program.

17. The computer program of claim 1 wherein the computer process further comprises:

garbage collecting the thread-specific data from the first thread-specific heap independently of garbage collection of the shared data in the shared heap.

18. The computer program of claim 1 wherein the computer process further comprises:  
garbage collecting the thread-specific data from the first thread-specific heap  
independently of garbage collection of a second thread-specific heap.

19. The computer program of claim 1 wherein the computer process further comprises:  
garbage collecting the thread-specific data from the first thread-specific heap  
independently of the execution of another program thread in the target program.

20. The computer program of claim 1 wherein the computer process further comprises:  
garbage collecting the shared data from the shared heap independently of garbage  
collection of the thread-specific data in the first thread-specific heap.

21. The computer program of claim 1 wherein the computer process further comprises:  
maintaining a remembered set identifying references to one or more shared data in the  
shared heap; and  
collecting the shared heap independently of garbage collection of the first thread-specific  
5 heap.

22. The computer program product of claim 1 wherein the computer process further  
comprises:  
collecting a portion of the shared data from the shared heap to leave an uncollected  
portion of the shared data in the shared heap, the uncollected portion of the shared data including  
5 shared data that is referenced by thread-specific data of the first thread-specific heap that has not  
yet been scanned;

scanning the thread-specific data from the first thread-specific heap, responsive to the operation of collecting a portion of the shared data; and

collecting the uncollected portion of the shared data from the shared heap, responsive to

10 the scanning operation.

23. The computer program product of claim 22 wherein the computer process further comprises:

collecting the thread-specific data from the first thread-specific heap, responsive to the operation of collecting a portion of the shared data.

24. The computer program product of claim 1 wherein the shared heap is shared by a subset of the program threads of the target program, wherein the subset of program threads includes less than all of the program threads of the target program.

25. A method of allocating of program data in a target program between one or more thread-specific heaps and at least one shared heap, the program data including thread-specific data and shared data, the method comprising:

analyzing the target program to distinguish between the thread-specific data of a first

5 program thread and the shared data;

configuring the target program to allocate the thread-specific data of the first program thread to a first thread-specific heap, responsive to the analyzing operation; and

configuring the target program to allocate the shared data to the shared heap, responsive to the analyzing operation.

26. The method of claim 25 wherein target program further includes a second program thread and the analyzing operation comprises:

identifying program data in the target program as the shared data, if the program data is referenced by the first program thread and the second program thread of the target program.

27. The method of claim 25 wherein the operation of configuring the target program to allocate the thread-specific data comprises:

replacing an original allocation instruction in the target program with a new instruction that allocates the thread-specific data of the first program thread to the first thread-specific heap

5 associated with the first program thread.

28. The method of claim 25 wherein the operation of configuring the target program to allocate the thread-specific data comprises:

leaving an original allocation instruction in the target program to allocate the thread-specific data of the first program thread to the first thread-specific heap associated with the first  
5 program thread.

29. The method of claim 25 wherein the operation of configuring the target program to allocate the shared data comprises:

replacing an original allocation instruction in the target program with a new instruction that allocates the shared data to the shared heap.

30. The method of claim 25 wherein the operation of configuring the target program to allocate the shared data comprises:

leaving an original allocation instruction in the target program to allocate the shared data to the shared heap.

31. The method of claim 25 further comprising:

collecting a portion of the shared data from the shared heap to leave an uncollected portion of the shared data in the shared heap, the uncollected portion of the shared data including shared data that is referenced by thread-specific data of the first thread-specific heap that has not  
5 yet been scanned;

scanning the thread-specific data from the first thread-specific heap, responsive to the operation of collecting a portion of the shared data; and



collecting the uncollected portion of the shared data from the shared heap, responsive to the scanning operation.

32. The method of claim 31 further comprising:

collecting the thread-specific data from the first thread-specific heap, responsive to the operation of collecting a portion of the shared data.

33. The method of claim 25 wherein the operation of configuring the target program to allocate the thread-specific data comprises:

configuring an allocation parameter associated with the thread-specific data indicating that the thread-specific data of the first program thread is to be allocated in the first thread-specific heap.



34. A compiler for managing allocation of program data of a target program between a shared heap and a thread-specific heap, the program data including thread-specific data and shared data, the compiler comprising:

a program analyzer analyzing the target program to distinguish between the thread-

5 specific data of a first program thread and the shared data; and

a code specializer configuring the target program to allocate the thread-specific data of the first program thread to a first thread-specific heap and configuring the target program to allocate the shared data to the shared heap, responsive to the analyzing operation.



35. A computer program product encoding a computer program for executing on a computer system a computer process for managing memory used for program data in a target program having one or more thread-specific heaps and at least one shared heap, the program data including thread-specific data and shared data, the computer process comprising:

5 allocating thread-specific data associated with a first program thread of the target program to a first thread-specific heap, the thread-specific data being determined to be reachable only by the first thread; and

allocating the shared data to the shared heap, the shared data being deemed potentially reachable by a plurality of the program threads of the target program.

36. The computer program of claim 35 wherein the computer process further comprises: garbage collecting the thread-specific data from the first thread-specific heap independently of garbage collection of the shared data in the shared heap.

37. The computer program of claim 35 wherein the computer process further comprises: garbage collecting the thread-specific data from the first thread-specific heap independently of the execution of another program thread in the target program.

38. The computer program of claim 35 wherein the computer process further comprises: garbage collecting the shared data from the shared heap independently of garbage collection of the thread-specific data in the first thread-specific heap.

39. The computer program of claim 35 wherein the computer process further comprises:  
maintaining a remembered set identifying references to one or more shared data in the  
shared heap; and

collecting the shared heap independently of garbage collection of the first thread-specific  
5 heap, based on the references identified in the remembered set.

40. A method of managing memory used for program data in a target program having one or more thread-specific heaps and at least one shared heap, the program data including thread-specific data and shared data, the method comprising:

allocating thread-specific data associated with a first program thread of the target  
5 program to a first thread-specific heap, the thread-specific data being determined to be reachable only by the first thread; and

allocating the shared data to the shared heap, the shared data being deemed potentially reachable by a plurality of the program threads of the target program.

41. The method of claim 40 further comprising:

garbage collecting the thread-specific data from the first thread-specific heap  
independently of garbage collection of the shared data in the shared heap.

42. The method of claim 40 further comprising:

garbage collecting the thread-specific data from the first thread-specific heap  
independently of the execution of another program thread in the target program.

43. The method of claim 40 further comprising:

garbage collecting the shared data from the shared heap independently of garbage  
collection of the thread-specific data in the first thread-specific heap.

44. The method of claim 40 further comprising:

maintaining a remembered set identifying references to one or more shared data in the  
shared heap; and

collecting the shared heap independently of garbage collection of the first thread-specific

5 heap, based on the remembered set.

45. The method of claim 40 further comprising:

collecting a portion of the shared data from the shared heap to leave an uncollected  
portion of the shared data in the shared heap, the uncollected portion of the shared data including  
shared data that is referenced by thread-specific data of the first thread-specific heap that has not  
5 yet been scanned;

scanning the thread-specific data from the first thread-specific heap, responsive to the  
operation of collecting a portion of the shared data; and

collecting the uncollected portion of the shared data from the shared heap, responsive to  
the scanning operation.

46. The method of claim 45 further comprising:

collecting the thread-specific data from the first thread-specific heap, responsive to the  
operation of collecting a portion of the shared data.

47. A memory manager for managing heap memory in a computer system, the heap memory being used to store program data, the program data including thread-specific data and shared data, the memory manager comprising:

an allocation module allocating thread-specific data associated with a first program thread of the target program to a first thread-specific heap, the thread-specific data being determined to be reachable only by the first thread, and allocating the shared data to the shared heap, the shared data being deemed potentially reachable by a plurality of the program threads of the target program.

48. The memory manager of claim 47 further comprising:

a garbage collector reclaiming memory associated with the thread-specific data from the first thread-specific heap independently of garbage collection of the shared data in the shared heap.

49. The memory manager of claim 47 further comprising:

a garbage collector reclaiming memory associated with the thread-specific data from the first thread-specific heap independently of the execution of another program thread in the target program.

50. The memory manager of claim 47 further comprising:

a garbage collector reclaiming memory associated with the shared data from the shared heap independently of garbage collection of the thread-specific data in the first thread-specific heap.

51. The memory manager of claim 47 wherein the memory manager maintains a remembered set identifying references to one or more shared data in the shared heap and further comprising:

a garbage collector reclaiming memory associated with the shared heap independently of

5 garbage collection of the first thread-specific heap, based on the remembered set.

09761404-011601  
FOUO-4049260